

R/V Albatross IV

AL9707 Cruise Report

June 18 - 28, 1997

Acknowledgements

We thank the officers and crew of the R/V ALBATROSS IV for their professionalism and friendly support. Their assistance enabled us to successfully complete the sampling operations and achieve the objectives of the GLOBEC survey of Georges Bank.

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Purpose of the Cruise

The U.S. GLOBEC Georges Bank Program is now into its third full field season. This year follows a major effort in 1995 to study the processes of physical stratification on the Bank and the response of the biota to stratification, followed in 1996 with reduced sampling effort to continue the time series of observations on the Bank. This year is the second major effort that is focused on studying the sources for water and organisms transported onto the Bank, the processes of their retention on the Bank, and the mechanisms by which water and organisms are transported off the Bank. The 1997 field program includes broad-scale cruises to map the distribution of physical and biological properties of the Bank. This cruise aboard the R/V ALBATROSS IV is the sixth broadscale cruise in a series of six cruises spaced at monthly intervals. Our effort was mainly devoted to developing a Bank-wide context for the process work being conducted in alternate years (1995, 1997, and 1999) and the modelers who will be using both the broadscale and process data in their model computations. Our specific objectives were:

- (1) To conduct a broadscale survey of Georges Bank to determine the abundance and distribution of U.S. GLOBEC Georges Bank Program target fish (eggs, larval and juvenile cod and haddock) and copepod species (*Calanus finmarchicus* and *Pseudocalanus* spp.).
- (2) To conduct a hydrographic survey of the bank.
- (3) To collect chlorophyll data to characterize the potential for primary production and to calibrate the fluorometer on the CTD.
- (4) To map the bank-wide velocity field using an Acoustic Doppler Current Profiler (ADCP).
- (5) To collect individuals of *C. finmarchicus*, *Pseudocalanus* spp., and the euphausiid, *Meganyctiphanes norvegica*, for

population genetics studies.

(6) To conduct lipid biochemical and morphological studies of *C. finmarchicus*.

(7) To conduct acoustic mapping of the plankton along the tracklines between stations using a high frequency echo sounder deployed in a towed body.

(8) To deploy drifting buoys to make Lagrangian measurements of the currents.

The cruise track was determined by the position of 40 "standard" stations and 39 "intermediate bongo" stations (located half-way between the standard stations) that form the basis for all of the broadscale cruises. The entire Bank, including parts that are in Canadian waters, was surveyed.

The work was a combination of station and underway activities. The along-track work consisted of high frequency acoustic measurements of the volume backscatter of plankton and nekton throughout the water column and surface measurements of temperature and fluorescence. The ship's ADCP unit was used to make continuous measurements of the water current profile under the ship, in order to construct the current field over the whole Bank. Meteorological data, navigation data, and sea surface temperature and salinity were logged by the ship's computer system.

A priority was assigned to each of the 40 standard stations that determined the equipment that was deployed during the station's activities. At high priority, full, stations, a bongo net equipped with a SeaBird CTD was towed obliquely to near the bottom. A CTD-fluorometer profile to the bottom was made and rosette bottles collected water samples for salinity and chlorophyll calibrations, chlorophyll concentrations, phytoplankton species counts, and $^{18}\text{O}/^{16}\text{O}$ water analysis. A large volume zooplankton pumping system was used to profile the water column. A 1-m² Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) was towed obliquely between the surface and the bottom cycling twice to first make vertically stratified collections for zooplankton (150 μm) and then to make collections of fish larvae (335 μm). Weather permitting, a 10-m² MOCNESS was towed obliquely to make vertically stratified collections of juvenile cod and haddock and the larger predators of the target species. At lower priority stations, a bongo tow, CTD profile, and 1-m² MOCNESS tow were made. At the intermediate stations, the SeaBird CTD/Niskin bottle cast was made for calibration purposes. A summary of the sampling events that took place during the cruise is in Appendix 1.

Cruise Narrative

The station numbers in the cruise narrative refer to "standard" station number (as opposed to consecutive station number).

18 June

After a delay of about 2hrs due to a fouled boom vang, the ALBATROSS IV departed Woods Hole under overcast skies and light winds at approximately 1600 hrs. with a full scientific party, but short handed on crew. Gear was rigged and supplies and spares tied down during the eastward trip through Vineyard sound.

19 June

The first station proceeded with no difficulties until a minor problem occurred during set up of the MOC1 which was remedied after an error was located in the calibration constants entered for the pressure sensor. During the subsequent tow, the cod end bucket of net 5 was lost resulting in no oblique sample from surface to depth. Station 2 was completed without problems. Large catches of ctenophores and some pteropods were taken in the MOC1. A problem with the dredge winch, which is used to tow the MOC10, delayed the completion of station 3 for approximately 2 hrs. At the end of the station there were several tears in the nets that required repair. At station 4, a serious loss of gear was narrowly averted when one of the tow points of the MOC10 partially broke away from its attachment to the frame during the tow. By making a substitution from another part of the frame, we effected a quick repair and made the net ready for the next tow.

20 June

The weather continued foggy without anything more than a glint of sun in the morning. Operations proceeded smoothly. The conductivity probe on the MOC10 had been performing erratically for the first four tows suggesting cable problems. An attempt to remedy the problem was made while underway between stations 6 and 7 by checking and realigning terminations. Station 7 was completed under relatively clear skies. The MOC 1 haul was interrupted at midpoint to allow freshly caught *Calanus* from the first half of the towing protocol to be brought aboard and removed from samples taken with the 150 micron nets. The conductivity probe remained nonfunctional for the MOC10 haul at station 7. Station 8 with a depth of 90m had the highest abundance of *C. finmarchicus* encountered. Large numbers of gelatinous zooplankton were observed drifting by the ship during the bongo and MOC1 tows. A problem with the MKV CTD recording erratic pressure values began to occur at stations 6 through 8.

21 June

The first day of summer dawned bright and sunny. No gear problems turned up at stations 9 and 10. With the relatively calm weather there seemed to have been less damage to the MOC10 than had occurred previously. Station 11 was in an area of large amounts of near-surface (0-10m) plankton that was visible from the deck and in the acoustic trace. Examined under the microscope, the sample from that depth had large numbers of bivalve larvae and hydroids. No further problems with the CTD pressure readings occurred. Stations 12, 13, 14 and were completed without difficulty. Of particular interest were significant amounts of sand in both MOC1 150 micron nets and pump samples from near the surface at station 12.

22 June

Station 16, the first deep station (875m), was completed and provided an interesting departure from the usual collections made at stations on the bank. The deepest net of the MOC10 (500-200m) brought up among a large number of Hyperiid amphipods, a large nemichthiid eel, an unusual very round very clear squid, several gonostomatids (*Chauliodus*, *Stomias*, and *Cyclothone*), a paralepidid and several species of euphausiids. During the tow, there was a substantial current to the southwest, making it impossible to tow through the station site without a sharp turn. The decision was made to steer a course that would minimize the drift

from that intended without turning sharply. The Greene Bomber was pulled out to re-rig the conductor cable after the steam to station 17 to reduce the drag on the conductor cable. Over the course of the afternoon the wind picked up from the SW to 20+ kt making operations a bit more of a challenge, but the work on deck proceeded nevertheless. The flow rate dropped during the pump profile at station 17 as it was brought up to shallow depths, and the problem reoccurred more seriously at the end of the profile at the next station. Eventually the hose was hauled in full of water. The assistance of the chief engineer was enlisted to dismantle the pump and look for potential leaks. The on-deck portion of the hose was checked for cracks and the hose was end for ended.

23 June

Station 19 proceeded smoothly under diminishing winds. The weather continued to improve and the day was bright and sunny. The overhaul of the pump seemed to have solved the problems experienced at stations 17 and 18. A major disaster with the Green Bomber nearly occurred when a winch cable fouled and put the entire strain of the towed body on the conductor cable. After breaking off the transect, reducing speed and bringing the fish on board, a loosened connection to the instrumentation was cleaned and resecured. Upon redeployment, all of the electronics functioned properly and the acoustic mapping resumed. Station 20 was carried out with no problems. At station 21 the sample from the MOC1 contained sand in the net that was sampling in midwater at 40-50m with a water column depth of 90m. Just before station 23, the strain relief for the signal cable from the acoustic fish gave way causing a loss of signal. It was brought aboard to assess the damage, some modifications were made to the routing of cables w/in the towed body, a heavier strain relief was attached, and the transect was resumed.

24 June

The fine weather continued as did the progress. No problems occurred at stations 24 and 39. Station 39, on the west side of the Northeast Channel, was particularly interesting. The MOC1 brought up one of the largest samples of *Calanus* in one of the surface (335 micron) nets but the concentration at the surface was much lower than in the previous surface net tow (150 micron). The near bottom samples were high in euphausiids along with the *Calanus*. This area was particularly rich in marine birds with the highest numbers of petrels and shearwaters. A right whale and another unidentifiable whale were seen in the vicinity suggesting feeding on the zooplankton patches. At station 25 on the east side of the Northeast Channel, an attempt was made to locate Peter Smith's guard buoys at the subsurface mooring site. Only one guard buoy was sighted and the information e-mailed to Peter. After the end of the station the ship put a small boat over the side to survey the area and to photograph the one remaining buoy which appeared to have no instruments. The next area around station 27 was being fished by three Canadian scalloping vessels. Sampling activities went smoothly and high densities of *Calanus* were taken from the near bottom MOC1 nets, a fact that was attested to by the blows of 5-8 marine mammals and some indication of fish schools on the surface at some distance from the ship. Weight was added to the Greene Bomber which was brought aboard briefly during the MOC10 tow in an unsuccessful attempt to adjust the underway orientation of the transducer beam.

June 25

The CTD trace began to show sync errors at station 28 but the cast was completed successfully. At station 29 the CTD cast was postponed until last in order to allow time for a retermination of the wire. However, the problem recurred at 140 m so only a partially successful cast was completed. The ship steamed towards the next station while the ETs continued to troubleshoot the system. The weather continued calm and station operations continued smoothly. The MOC1 haul at station 29 contained huge numbers of *C. finmarchicus* in the #5 net which was towed obliquely from surface to depth. Similar concentrations did not occur at any of the discrete-depth stations suggesting a highly contagious distribution. Marine mammal sightings continued to be frequent in the area. There were six 20-mm cod in the near surface MOC 10 sample and abundant amphipods from all strata, especially the deepest. At station 30 the MOC1 appeared to have hit the bottom. The O₂ net contained substantial amounts of sand and shell fragments. The CTD functioned satisfactorily at the 49m depth of station 30 as well as at 183m at station 40. *Calanus* were abundant at station 40 along with a moderate number of pteropods.

26 June

A moderate breeze disturbed the nearly flat calm surface of the previous day. At station 32, there was a lot of particulate matter near the surface. Catches in the MOC1 were moderate. All equipment functioned well through stations 31 and 32, with the exception of the conductivity sensor on the Greene Bomber on the transect between stations 31 and 32. The towed body was brought aboard at 32 and a chafed cable located and repaired. The Bomber was back repaired and back sampling by the end of the MOC1 haul. At station 33 there was an unusually large catch of haddock juveniles--18 specimens ranging in size from 16 to 30mm. There was a tear in the corner of the no. 3 net of the MOC10. The entire corner rope had given way and a substantial repair was required. Relative biomass from these tows appear to be lower than those taken in the deeper water to the north.

27 June

Stations 34 -36 proceeded smoothly with no problems. At station 37 contact with the deck box (modem) of the MOC1 was lost. A dead battery was suspected and it was replaced, but did not cure the problem. It was eventually solved by shutting down and restarting and the computer completely. The tow was then completed successfully. The MOC1 tow was followed by an experiment to observe and acoustically map secondary cell circulation on the shoals of the bank. A CTD cast was made initially to establish that the water column was well mixed. This was followed by a pump cast and a MOC1 haul to sample the suspended material and biological acoustic targets in the water column. A home brew drogue was assembled by the deck watch under Willie Amaro's direction and released at 15m at the site. The ship then steamed around a 1nm grid of 6 legs with the drogue for orientation. The drogue was then retrieved and a 1nm transect with the CTD was made to record variation in the fluorescence associated with local circulation patterns. After the CTD transect the vessel steamed off to complete station 38. The final station was completed successfully and the acoustic transect terminated. After a live tow for *Calanus* the final drifter was deployed at 10m and the vessel began the steam back to port.

GLOBEC Broadscale Survey Reports

Hydrography

Maureen Taylor, Alyse Weiner

The primary hydrographic data presented here were collected using a Neil Brown Mark V CTD instrument (MK5), which provides

measurements of pressure, temperature, conductivity, fluorescence and light transmission. The MK5 records at a rate of 16 observations per second, and is equipped with a rosette for collecting water samples at selected depths.

Bongo hauls were made at each of the stations occupied. A Seabird Electronics Seacat model 19 profiling instrument (SBE19 Profiler) was used on each bongo tow to provide depth information during the tow. Pressure, temperature, and salinity observations were recorded twice per second by the Profiler.

The following is a list of the CTD data collected with each of the sampling systems used on the cruise:

Instrument	# Casts
MK5	41
MK5 calibration	38
SBE19/Bongo	40
SBE19 calibration	5

The MK5 was deployed with 6 bottles on the rosette and samples were collected for various investigators. At primary #1 and #2 stations, 400 mls were immediately siphoned out of two niskin bottles (bottom and mid-depth) for observations of micro-zooplankton swimming behaviour (S. Gallagher, Woods Hole Oceanogr. Inst.). Samples were collected for oxygen isotope analysis at selected depths for R. Houghton (Lamont Dougherty Geol. Obs.) and a sample was taken at the bottom for calibrating the instrument's conductivity data. Chlorophyll samples were taken from three depths at "full" stations and were filtered for total chlorophyll concentrations. These samples will be analyzed at the Univ. of Maine (D. Townsend). Surface samples for phytoplankton species composition were collected and preserved for J. O'Reilly (NOAA/NMFS, Narragansett, RI) at "full" (priority 1 and 2) stations only.

Parameter	# samples taken
Oxygen isotope	140
Chlorophyll	56
Species composition	19

Data:

The SBE19 Profiler and the MK5 data were post-processed at sea. The Profiler data were processed using the Seabird manufactured software: DATCNV, FILTER, ALIGNCTD, BINA VG, DERIVE, ASCIIOUT to produce 1 decibar averaged ascii files. The raw MK5 data files were processed using the manufacturer's software CTDPOST in order to identify bad data scans by "first differencing". The latter program flags any data where the difference between sequential scans of each variable exceed some preset limit. The "Smart Editor" within CTDPOST was then used to interpolate over the flagged values. The cleaned raw data were converted into pressure averaged (1 decibar) files using algorithms that had been adapted for use with the MK5, provided by WHOI (R. Millard).

At station #26, we began to see sync errors in the data during the MK5 cast. At the next station, the cast had to be aborted because of total loss of the signal. After a fair amount of trouble-shooting, it was concluded that there was a short in at least one of the conductors. The cable end-fitting and splice were replaced and the MK5 CTD was again operational by station #30. Seabird CTD data will be used as the primary hydrographic data for stations 28 and 29.

RESULTS:

The consecutive and standard station locations occupied during the bank-wide survey are shown in figure 1. The surface and bottom temperature and salinity distributions are shown in figures 2 & 4. Surface and bottom anomalies of temperature and salinity as well as a stratification index (sigma-t difference from the surface to 30 meters) were calculated using the NMFS-Northeast Fisheries Science Center's MARMAP hydrographic data set as a reference. Anomaly distributions are shown in figures 3, 5, & 6. The distribution of fluorescence (expressed in volts) at the surface and bottom is shown in figure 7. These figures were prepared prior to the occupation of standard station 38.

The volume-average temperature and salinity of the upper 30 meters were calculated for the four sub-regions shown in Figure 8. These values were compared with characteristic values that have been calculated from the MARMAP data set for the same areas and calendar days. The volume of Georges Bank water (salinity < 34 psu) was also calculated and compared against the expected values. Profiles of each MK5 CTD cast with a compressed listing of the data are given in Appendix 1.

Relatively warm temperatures and salinities were observed at standard stations 3 and 7 and are believed to be the result of two warm core rings that were seen in satellite imagery prior to our departure. The negative volume anomalies (figure 8) shown for the southwest and southeast regions indicate that there was less "Bank water" in these regions (water having salinity >34.0 psu are excluded from the calculations shown in figure 8).

As had been observed throughout the 1997 field season, the surface and bottom salinity anomaly distributions again show that the Bank is experiencing "fresher" conditions relative to the MARMAP reference period. The upper 20m of the water column at standard station 34 was < 32.0 psu. The Bank wide temperature distributions were consistent with the expected conditions for mid - late june (with the exception of those stations believed to be influenced by Gulf Stream rings and the stations in the extreme northwest corner of the Bank). Scotian Shelf water was not observed on the Bank during this survey.

Zooplankton and Ichthyoplankton Studies based on Bongo and MOCNESS tows.

(John Sibunka, Maria Casas, Jack Green, Antonie Chute, Alyce Jacquet, Dorothy Schreiber, Sarah Gregg, Neile Mottola, and Stephen Brownell)

Objectives:

(1) Principle objectives of the ichthyoplankton group in the U.S. GLOBEC Georges Bank Broadscale Surveys were to study the composition of the larval fish community on Georges Bank, to define larval fish distribution across the Bank and within the water column, to determine those factors which influence their vertical distribution, and to determine bank-wide versus "Patch-Study" mortality and growth rates. Emphasis in this study is on cod and haddock larvae, and their predators and prey. This study also includes larval distribution and abundance, and age and growth determinations. Bongo net and MOCNESS were used to collect

samples of the larval fish community.

(2) The primary objective of the zooplankton group was to complete a bank-wide survey of Georges Bank to determine the distribution, abundance, and stage composition of the target species *Calanus finmarchicus* and *Pseudocalanus* spp. A second objective was to identify, quantify, and describe the occurrence of abundant non-target species in order to provide a description of the environment occupied by the target species. A 1-m² MOCNESS, a vertically discrete, multiple opening and closing net system was used to sample copepods and larger zooplankton, and a submersible pump to sample the small, naupliar stages.

In addition to these objectives, the zooplankton group was responsible for:

(a) Taking subsamples from the 1-m² MOCNESS hauls for population genetic studies of *Pseudocalanus* spp. to be completed by Dr. A. Bucklin at the University of New Hampshire.

(b) Collecting live *Calanus finmarchicus* at Standard station #38. These samples will be used for an ongoing immunology study at the Woods Hole Oceanographic Institute.

Methods:

Bongo tows were made with a 0.61-m frame fitted with paired 335 μ m mesh nets. A 45 kg ball was attached beneath the bongo frame to depress the sampler. Digital flow meters were suspended in the mouth of each net to determine the volume of water filtered. Tows were made according to standard MARMAP procedures, (i.e., oblique from surface to within five meters of bottom or to a maximum depth of 200 m while maintaining a constant wire angle throughout the tow). Wire payout and retrieval rates were 50 m/min and 20 m/min respectively. These rates were reduced in shallow water (<60 m) to obtain a minimum of a five minute tow or reduced due to adverse weather and sea conditions. A Seabird CTD was attached to the towing wire above the frame to monitor sampling depth in real time mode and to measure and record temperature and salinity. Once back on board, the 335 μ m mesh nets were rinsed with seawater into a 335 μ m mesh sieve. The contents of one sieve were preserved in 5% formalin and kept for ichthyoplankton species composition, abundance and distribution. The other sample was preserved in 95% ethanol and kept for age and growth analysis of larval fish. The same preservation procedure was followed as for the 1-m² MOCNESS.

At stations where the 1-m² MOCNESS system either was not towed or could not be used due to adverse weather conditions, a second bongo tow was made. This frame was fitted with both 335 μ m mesh and 200 μ m mesh nets. Digital flow meters were suspended in the mouth of each net to determine the volume of water filtered. Tows were made according to standard MARMAP procedures except maximum tow depth was 500 m. Wire payout and retrieval rates were 50 m/min and 20 m/min respectively. The nets were each rinsed with seawater into a corresponding mesh sieve. The 200 μ m mesh sample was retained for zooplankton species composition, abundance and distribution, and preserved in 10% formalin. The other sample (335 μ m mesh) was kept for molecular population genetic analysis of the copepod, *Calanus finmarchicus*, and preserved in 95% ethanol. After 24 h of initial preservation, the alcohol was changed.

The 1-m² MOCNESS sampler was loaded with ten nets. Nets 1-4 were fitted with 150 μ m mesh for the collection of older and larger copepodite and adult stages of the zooplankton. Nets 0, and 5-9 were fitted with 335 μ m mesh for zooplankton (nets 0 and 5) and ichthyoplankton (nets 6-9) collection. Tows were double oblique from the surface to within 5 m from the bottom. The maximum tow depth for nets 0, 1 and 5 was 500 m, and for net 6 was 200 m (if net 5 was sampled deeper than 200 m, it was returned up to 200 m and closed). Winch rates for nets 0-5 were 15 m/min and for nets 6-9, 10 m/min. The depth strata sampled were 0-15 m, 15-40 m, 40-100 m, and >100 m. The first (#0) and sixth (#5) nets were integrated hauls. For shallow stations, with only 2 or 3 of the depth strata, not all nets were fished. The contents of nets 0-4 were sieved through 150 μ m mesh sieve, subsampled using a 2-L plankton sample splitter if the final biomass volume was too large for one quart jar, and then preserved in 10% formalin. Samples from nets 5-9 were sieved through 330 μ m mesh sieve and preserved in 95% ethanol. After 24 h of initial preservation, the alcohol was changed. The used ethanol was retained for disposal or recycling ashore. At priority 1 and 2 stations and at station 40, 90-ml subsamples from nets 1-4 (150 μ m mesh) were removed and preserved in 10% formalin for Dr. C. Miller (Oregon State Univ.). At priority 1 and 2 stations, 90-ml subsamples from nets 2, 3, and 4 were removed and preserved in 95% ethanol. These samples were collected for Dr. A. Bucklin for population genetic studies to distinguish the *Pseudocalanus* species found on Georges Bank. At stations deeper than 150 m where C. Miller required subsamples for live analysis, the 1-m² MOCNESS was hauled out after the first oblique. Samples from nets 0-4 were collected and the MOCNESS was then immediately redeployed to complete the tow.

The 10-m² MOCNESS was loaded with five 3.0 mm mesh nets. Tows were oblique from surface to ~10 m from bottom or a maximum depth of 500 m. The same depth strata were sampled as with the 1-m² MOCNESS. The winch rate for retrieval varied between 5 and 20 m/min depending on the depth stratum. The slow winch rates were used in order to filter at least 4,000-5,000 m³ of water per depth stratum sampled. A stepped oblique tow profile during retrieval was used to achieve this, if needed. Catches were sieved through a 335 μ m mesh, and preserved in 10% formalin.

The Pacer high-volume pump was used to collect nauplii and younger, smaller copepodite stages of zooplankton. The intake hose was deployed off the port side hydro boom by connecting the suction end, fitted with a 1.7-L Niskin bottle cut in half lengthwise, to the winch wire. The boom winch meter block was zeroed at the surface and the wire out reading was used to determine the depth of the cast. Two 45 kg weights were used to depress the array. Three 30-m sections of 7 cm diameter hose were connected to the pump, allowing the intake hose to attain a maximum depth of approximately 82 m. At shallow stations, the intake hose nozzle was lowered to 3-5 meters off the bottom. Three integrated depth samples were collected with 35 μ m mesh nets, sieved through a 30 μ m mesh sieve and preserved in 10% formalin. Sampling depths were from the maximum depth to 36 m, 36-11 m, and from 11 m to surface. Before samples were collected, water was diverted from the net and the hose was allowed to flush for 60 seconds. This assured that zooplankton from the desired strata were obtained. Once at the surface, the intake section was held just below the surface for 60 s. This allowed the water to pass completely through the hose. Wire retrieval rate was approximately 4 m/min. This rate was used to obtain volumes of 500 L per 5 m depth interval sampled.

Tow for live specimens:

The 0.61-m bongo frame fitted with paired 335 μ m mesh nets and depressed with a 45-kg weight was used to collect live specimens of *Calanus finmarchicus*. A smooth oblique tow was made from surface to depth (50 meters of wire was paid out) and fished at maximum depth for two minutes. Winch rates were ~40 m/min for payout and 5 m/min haulback. Vessel speed was 1.5 kts.>

Preliminary Results--Zooplankton

Zooplankton from the 1-m² MOCNESS samples from nets 0-4, and all pump samples will be identified, staged, and enumerated at the University of Rhode Island, Graduate School of Oceanography.

Georges Bank zooplankton had settled into its summer pattern. On the crest, within the 60 m isobath, the copepods were primarily *Temora longicornis* and *Centropages hamatus*. *Pseudocalanus* spp. was present in lesser and more variable numbers. *Calanus finmarchicus* was found in abundance in deeper waters between 60-100 m, specifically the northeast peak of the bank and along the stations on the southern flank. At station 39 and 25, *C. finmarchicus* patchiness was evident in the 1-m² MOCNESS double oblique tows. The first half of the tow contained completely different abundances of *C. finmarchicus* than the second half. The deep stations around the bank >100 m were dominated by *C. finmarchicus*.

The hydroid *Clytia* that was so abundant during the June 1996 broadscale cruise was present in very low numbers and only in a few stations.

Following are general observations on the plankton assemblages made at many, but not all of the stations during this cruise using net 0 (surface to bottom - 335 μ m) on the 1-m² MOCNESS.

Station 1,..... Copepod assemblage composed mostly of *Temora longicornis* and *Pseudocalanus* spp. *Centropages hamatus* were present in lesser numbers. Very few *C. finmarchicus*. The chaetognath, *Sagitta elegans*, was abundant in every net. Also seen were crab zoeas, and bivalve post-larval stages.

Station 2,..... Similar assemblage as at previous station, but more *C. finmarchicus* were seen, mostly stage C3 and older. Non-copepods were represented by numerous ctenophores and other gelatinous zooplankton.

Station 3,..... *C. finmarchicus* was moderately abundant here, younger stages were also seen. *Pseudocalanus* spp. was very abundant. Moderate numbers of the shelled pteropod, *Limacina* spp., were in the samples.

Station 4 and 5,..... Samples made up almost entirely of *C. hamatus* and *T. longicornis*, with few *Pseudocalanus* and *C. finmarchicus*. Abundant numbers of medusae were present in all the nets.

Station 6,..... Mostly older stages of *C. finmarchicus* were found in abundance. Chaetognaths and pteropods were also present.

Station 8 and 9,..... Samples were full of older stages of *C. finmarchicus*.

Station 10,..... *T. longicornis* and *Pseudocalanus* were the dominant copepods at this station. *Centropages* spp. and *C. finmarchicus* were absent. Medusae were once again very abundant.

Station 11,..... *Pseudocalanus* and *C. hamatus* were the main copepods at this station. *C. finmarchicus* was again absent. Moderate numbers of polychaetes and bivalve post-larval stages were seen. Very fine sand was found in all the samples, even the surface net.

Stations 12, 13, 14, and 15,..... *C. finmarchicus* was absent from the central part of the bank. The copepods were made up mostly of *C. hamatus*, *T. longicornis* and *Pseudocalanus* spp.

Station 17,..... *C. finmarchicus* were abundant again at this station, and a moderate number of *Metridia lucens* were seen.

Station 20,..... Typical Georges Bank copepod mix: *Pseudocalanus* spp., *T. longicornis*, and *Centropages* spp. Chaetognaths were moderately abundant, as were cumaceans and a few hydroids.

Station 21,..... Most abundant was *Pseudocalanus* spp., with moderate numbers of *T. longicornis*, *C. hamatus*, and *C. finmarchicus*. Chaetognaths and hyperid amphipods were also in moderate numbers.

Stations 39 and 25,..... *C. finmarchicus* concentration at both of these stations was very patchy. i.e. the surface net of the 150 μ m mesh nets of one cast contained very minimal numbers, whereas in the corresponding net of the second oblique, 335 μ m mesh nets, 2 quart jars were filled with *Calanus*.

Station 26,..... Abundance of *C. finmarchicus* in all the nets sampled together with some *Pseudocalanus* spp. and *T. longicornis*. Shelled pteropods and medusae were also in the samples.

Station 27 and 28,..... Typical Georges Bank mix of copepods (*Pseudocalanus* spp., *Centropages* spp., and *T. longicornis*). Very few *C. finmarchicus*.

Station 29,..... *C. finmarchicus* very abundant. Also many *Euchaeta norvegica* females with eggs were seen.

Station 30, 31 and 32 Sand found in the samples. Typical bank mix of copepods with very few *C. finmarchicus*. Other non-copepods seen were chaetognaths, polychaetes, and bivalve post-larval stages.

Samples Collected by the Zooplankton and Ichthyoplankton Groups:

Gear		Tows	Number of Samples
1.	Bongo nets, 0.61-m	40 tows	
	335 μ m mesh		40 preserved, 5% formalin
	335 μ m mesh		40 preserved, EtOH
2.	MOCNESS, 1-m ²	41 tows	
	150 μ m mesh		168 preserved, 10% formalin
	335 μ m mesh		162 preserved, EtOH

3. MOCNESS, 10-m² 32 tows 126 preserved, 10% formalin
 3.0-mm mesh

4. Pump 20 profiles 62 preserved, 10% formalin
 30 um mesh

Preliminary Summary--Ichthyoplankton

Antonie Chute, John Sibunka, Jack Green

All samples collected for ichthyoplankton analysis (bongo nets A and B, nets 6-9 from the 1-m² MOCNESS, 10 m² MOCNESS) were examined for fish eggs and larvae on board the ship, as most of the cod and haddock spawned in early spring were big enough to avoid the bongo, yet able to be caught by the 10 m² MOCNESS. Bongo samples were examined in jars after preservation, and 10 m² MOCNESS samples were examined live in a bucket. Cod and haddock larvae/juveniles were removed from the 10 m² MOCNESS samples, measured individually and preserved in ethanol for further study.

Cod (*Gadus morhua*)

Most of the cod collected on the cruise were caught by the 10m² MOCNESS. Only four individuals were seen in the bongo samples, and they were all less than 17mm in length. The cod captured in the 10 m² MOCNESS ranged from 11 to 33mm and averaged 23mm total length. On the June, 1996 cruise, we expected to see cod larvae and juveniles on the northern part of the bank, but found them all over the bank with an apparent concentration in the southwest at stations 1 and 2. A similar pattern was evident this year. The cod catches were small (generally less than 5 larvae per station) and scattered over the bank. Most catches of three or more individuals occurred on the southwest portion of the bank, up the southern flank and onto the northeast peak. Catches were generally lighter on the northern flank.

Haddock (*Melanogrammus aeglefinus*)

The haddock larvae and juveniles collected were also mainly from the 10 m² MOCNESS. Only 5 individuals were observed in the bongo samples, whereas 136 were counted and measured from the 10 m² MOCNESS. As with the cod larvae and juveniles, the haddock collected with the bongo net were smaller (average total length ~10.5mm) than those collected with the 10 m² MOCNESS (average total length 21.2mm, range 11 to 50mm). Most of the haddock collected in the 10 m² MOCNESS were caught at stations 29, 30, 31, 40, 32, 33, 34 and 38 along the northern flank of the bank.

Yellowtail flounder (*Limanda ferruginea*) and American plaice (*Hippoglossoides platessoides*)

These fish were the most abundant larvae in the bongo and 10 m² MOCNESS catches. It was difficult to tell the two species apart without the aid of a microscope (especially when there were many small larvae in a jar), so for the purposes of this report they were combined into one group. However, it is likely that the majority of the smaller larvae were yellowtails, as they spawn later into the summer than the plaice. Yellowtail/plaice larvae were caught at almost every station visited, with the largest (to ~16mm) from the 10 m² MOCNESS. The biggest catches were from the southern flank between the 60 and 100m isobaths (stations 6, 9, 15 and 18) and the northeast peak of the bank (station 23 and 24). These samples contained hundreds of larvae usually under 10mm in total length.

Fish eggs: The few (just a couple visible in each sample jar) cod/pollock/haddock eggs observed during this cruise were found at station 3 in the southwest corner of the bank, and at stations 27 and 28 on the northeast peak. Most of the fish eggs observed in the samples were half the size of the cod/pollock/haddock eggs, and came from the middle of the bank. There is a good chance they were hake eggs, as tiny *Urophycis* larvae were seen in the samples.

Miscellaneous larvae

The following larvae were also identified in the ichthyoplankton samples:

Atlantic mackerel (*Scomber scombrus*)
 Windowpane flounder (*Scopthalmus aquosus*)
 Smallmouth flounder (*Etropus* sp.)
 Lanternfish (family Myctophidae)
 Hake (*Urophycis* sp.)
 Snailfish (*Liparis* sp.)
 Redfish (*Sebastes* sp.)

Preliminary Summary--10 m² MOCNESS

The 10-m² MOCNESS was deployed 32 times during the cruise. Sample sizes varied widely, from two gallons of euphausiids to a couple of ctenophores. Below is a brief summary of catches per station, based on observation of preserved samples in jars. The catches are listed in descending order of biomass.

Standard station 3, Haul 1

(Tiny samples)
 Amphipods
 Small medusae
 Phyllosoma larvae
 Octopus/squid

Standard station 4, Haul 2

Brown jellyfish (Lion's mane type)
 Isopods
 Large hydroid branches

Standard station 5, Haul 3

Ctenophores
 Brown jellyfish

Isopods
Leptocephalus larva
Razor clams (several, to 20mm)
Dogwinkle-like snails (2, alive when caught)
Amphipods

Standard station 6, Haul 4

Brown jellyfish
Ctenophores
Leptocephalus larvae
Small medusae
Fish larvae

Standard station 7, Haul 5

Several quarts of hyperiid amphipods
Siphonophore parts
Fish larvae

Standard station 9, Haul 6

Brown jellyfish
Amphipods
Isopods
Large worms
Naked pteropods
Fish larvae

Standard station 10, Haul 7

Brown jellyfish
Isopods
25mm razor clam
Fish larvae

Standard station 11, Haul 8

Large hydroid branches
Bits of macroalgae and hay
Nudibranchs
Fish larvae

Standard station 12, Haul 9

Large hydroid branches
Brown jellyfish

Standard station 13, Haul 10

Brown jellyfish
Hydroid branches
Ctenophores

Standard station 14, Haul 11

Ctenophores
Brown jellyfish
Isopods
Leptocephalus larvae
Regular fish larvae

Standard station 16, Haul 12

Nets 0 and 1: 3 gallons of euphausiids
Net 2: a few hyperiid amphipods
Nets 3 and 4: 1 gallon of hyperiid amphipods

Standard station 17, Haul 13

(Tiny samples)
Hyperiid amphipods
Naked pteropods
Small medusae
Euphausiids
Phylosoma larva

Standard station 18, Haul 14

Ctenophores
Isopods
Brown jellyfish
Hydroid branches

Standard station 19, Haul 15

Brown jellyfish
Isopods
Decapod shrimp (*Crangon*)

Standard station 20, Haul 16

(Very small samples)

Ctenophores
Hydroid branches
Naked pteropods

Standard station 21, Haul 17
(Very small samples)
Ctenophores
Hydroid branches
Leptocephalus larvae
Naked pteropods
Regular fish larvae
Razor clam

Standard station 23, Haul 18
(Tiny samples)
Sand lance juveniles
Fish larvae
Naked pteropods
Isopods, large copepods

Standard station 39, Haul 19
Gallons of euphausiids at depth
Hyperiid amphipods toward the surface

Standard station 25, Haul 20
Hyperiid amphipods
Large chaetognaths

Standard station 26, Haul 21
Naked pteropods
Amphipods

Standard station 27, Haul 22
Isopods
Hydroid branches
Amphipods

Standard station 28, Haul 23
(Tiny samples)
Isopods
Amphipods
Naked pteropods

Standard station 29, Haul 24
Amphipods
Medium shrimp
Large copepods
Euphausiids

Standard station 30, Haul 25
Brown jellyfish
Fish larvae
Large copepods

Standard station 40, Haul 26
Euphausiids
Hyperiid amphipods

Standard station 31, Haul 27
Brown jellyfish
Euphausiids
Amphipods

Standard station 32, Haul 28
Sticks, hay and plant bits
Hydroid branches
Brown jellyfish
Ctenophores
Nudibranchs
Isopods

Standard station 33, Haul 29
Ctenophores
Naked pteropods

Standard station 34, Haul 30
Naked pteropods
Large shrimp
Euphausiids
Ctenophores

Large copepods

Standard station 36, Haul 31

Brown jellyfish
Isopods
Amphipods
Fish larvae

Standard station 38, Haul 32

Euphausiids (10 quarts)
Medium shrimp
Ctenophores

Copepod Life History Studies

Jennifer Crain, Charles B. Miller, Oregon State University

***Calanus* sex reversal? : the quadrithek story continues**

There is a large body of evidence supporting the hypothesis that genetic male copepods of the family Calanidae have a point in their development at which they can "choose" to develop as functional females, and that this "choice" is triggered by some unknown environmental signal. Laboratory rearing studies and field-observed sex ratios support this. The signature of females resulting from this change is a male setal pattern on the first antenna. Fleminger (1985) saw this pattern in females of a number of calanid species, and called them "quadritheks" because they (like males) have four setae on some of the segments in contrast to normal, or "trithek", females, which have only three. We have found definite seasonal trends in the proportions of quadritheks in our Georges Bank samples from 1994, 1995 and 1996. The same trend has been seen by colleagues (Svensen and Tande) in Norway. We will continue to monitor this trend using formalin-preserved subsamples from the 150 micron MOC-1 nets on this and subsequent broadscale cruises. On AL 9707, we collected subsamples (90/600ml) at standard stations 3, 4, 7, 8, 9, 12, 13, 16, 17, 18, 20, 23, 25, 39, 27, 29, 30, 40, 34, 36 and 38 for analysis of first antennal setation patterns.

We hope that we will be able to determine the underlying genetic sex of individual *Calanus* and correlate the quadrithek antennal morphology with genetic maleness. We will try to tackle this problem by analysis of DNA fragment lengths, which are expected to be different in X and Y chromosomes, and by searching for highly multiple repeat sequences characteristic of sex chromosomes. For these analyses, we have been cryopreserving adult male and female *Calanus*. Very few adult *Calanus* were found during this cruise, so none were frozen in liquid nitrogen. Ethanol-preserved subsamples from MOC-1 net 5 (90/400ml) taken at standard stations 3, 4, 7, 9, 12, 13, 16, 17, 18, 20, 23, 25, 39, 27, 29, 30, 40, 34, 36 and 38 will be used to augment samples from previous cruises for biochemical analyses.

The question of relative egg outputs of normal (trithek) females versus sex-changed genetic males (quadritheks) and implications for individual reproductive success will be addressed by correlations between fecundity data gathered by Jeff Runge and analysis of antennal morphology for each specimen. There are some intriguing questions left to be answered regarding the impact of sex reversal on *Calanus* population dynamics. We are trying, by examination of subsamples from GLOBEC broadscale surveys, and cooperative efforts with other GLOBEC scientific investigators, to piece the whole story together.

Copepodite jaw morphology: an indicator of diapause and age-within-stage

We have been analyzing jaw facies of fifth copepodites to determine the fractions of their stocks that are A) entering the copepodite resting stage typical of this species, and B) preparing for immediate maturation. Copepodites of the A group retain the postmolt facies, a large hemocoele extension which looks like a transparent bubble reaching up toward the teeth of the mandibular gnathobase. Copepodites of the B group also have this 'bubble' for a short period following molting, but it begins retracting toward the base very quickly as the animal fills its new exoskeleton. We are dissecting and examining the jaws of individuals from the formalin-preserved subsamples listed above to determine the proportions of animals in this jaw phase. Additional correlations of jaw stage data with gonad development and oil sac volume, both indicators of whether a copepodite is halting or proceeding with development to maturity are being made to differentiate between the groups.

Observations of lipid volumes as seen on images captured (see below) showed that there were many fifth copepodites with large volumes of stored oil, especially at the deeper stations. Some of these animals were still active, but many were not, and were assumed to have entered diapause. Developing gonads were seen only in animals with smaller oil sacs.

Jaw phase is also an indicator of an individual's age-within-stage. As the animal progresses through each stage, the jaw facies pass through recognizable postmolt, late postmolt, intermolt and tooth formation phases. Rate of progression through this series of jaw phases may be variable, possibly related to feeding or starvation history. Preliminary analyses of jaw phases of individual second through fifth copepodites from subsamples taken from 1995 and 1996 broadscale surveys, have yielded some interesting results with respect to the population dynamics of *Calanus* on Georges Bank. The formalin-preserved subsamples listed above will be used for continuation of this effort.

Lipid analyses : total storage volume and composition

We are studying the large store of oily wax which *C. finmarchicus* secretes into a tubular sac in the prosome of the fifth copepodite stage, prior to either maturation or rest. Actually, all copepodite stages have such sacs and accumulate some oil. The main question under study in 1997 is the areal and seasonal variation in quantities of oil in C5. Oil is quantified by an integration of the projected area of the oil sac in video pictures and approximate conversion to oil volume, using image analysis and an algorithm recently worked out by C. Miller for calculating an accurate volume estimate from the area.

On AL 9705, sets of video recordings were taken at standard stations 8, 16, 18, 23, 39, 29, 40, 34 and 38. It is necessary to have undamaged, healthy individuals for these images. The animals caught in some of the deeper (longer) MOC-1 hauls on the previous cruise were dead or dying by the time they were sorted from the nets, and could not be used. To circumvent this problem, interrupted MOC hauls were made at the deeper stations on this cruise (7, 16, 39, 29, 40, 34 and 38), and the first five nets (0-4) were rinsed before redeploying for the rest of the tow. These hauls yielded strong, healthy fifth copepodites for images. Each image recorded was of a group of five fifth copepodites. Each group was then cryopreserved for gas chromatographic analysis of fatty acid and fatty

alcohol components.

Microzooplankton Studies: The Importance of Microzooplankton in the Diet of Newly Hatched Cod Larvae; and Broadscale Studies of Prey Abundance

Sarah Gregg, Neile Mottola

The objective of this study is to determine the seasonal changes in the potential prey field for newly hatched cod larvae with respect to prey motility patterns and the prey size spectrum.

Prey Size, Abundance and Motility Observations

Observations were made and recorded for analysis of motility patterns and the size spectrum of available prey from three locations in the water column--near bottom, mid- and near surface well-mixed areas at all high priority (#1 and #2 stations) on the six GLOBEC Broadscale surveys of Georges Bank, January through June, 1997.

Water samples were collected from near bottom and from the pycnocline of the water column using Niskin bottles on a Neil Brown Mark V CTD. Surface samples were collected with a plastic bucket. Niskin bottle samples were collected by gently siphoning from the top of the bottle instead of the port so that the microplankton were not disrupted. Two hundred fifty-ml tissue culture flasks were filled after being dipped in soapy water and air dried to prevent fogging. To further prevent fogging as well as maintain a constant low temperature, all the flasks were transferred to a refrigerator (5 degrees C.) immediately after filling.

Each flask, in turn, was placed in a holder across from a B/W high-res Punix camera fitted with a 50 mm macro lens and directly in front of a fiber optic ring illuminator fitted with a far-red filter. This apparatus was suspended within the incubator by bungee cord to reduce vibration produced by the ship. Recordings were made using a Panasonic AG1980 video recorder with Sony SVHS formatted cassettes, a Panasonic TR-124MA Video Monitor, and a timing device for a period of fifteen minutes for each sample. The flask was then replaced with the next sample and contents recorded.

At each priority one station of cruise AL 97-07 samples were taken, recorded and preserved. All priority one samples were preserved in 10% Lugols, except stations #29, #36, #38 and #39, due to the fact that the Lugols ran out. All priority 2 stations, with the exception of station #29 were sampled and recorded, but not preserved in Lugols.

Post cruise processing

Motility patterns will be analyzed with the Motion Analysis EV system. The final output will be particle size distribution and a motility spectrum associated with each particle. This will be compared with species composition in the microzooplankton fraction preserved in Lugols.

Genetic Studies

Neile Mottola

Population genetic studies of *Calanus*, *Pseudocalanus*, and several other species are being conducted at the University of New Hampshire. Individuals are believed to come onto Georges Bank from the Gulf of Maine, Gulf of St. Lawrence, Scotian Shelf, and possibly the Slope Water. However, it has not been possible to discern morphological differences between individuals originating from separate areas off the bank. This work is tied directly to other efforts to identify water sources and losses for the bank, as well as circulation and exchange processes across the bank boundaries.

During this cruise pure samples of *Calanus* were strained, bagged, tagged and frozen in liquid nitrogen to be used later in the genetic studies mentioned above. Our understanding of pteropods on the bank is also somewhat limited. There are two subarctic species that are known to occur in and around Georges Bank: *Limacina retroversa* (dominant species) and *Limacina helicina*. These species occur in both hemispheres which indicates a bipolar distribution. Bipolarity can be explained by climatic warming during the recent geological past which has caused the present-day separation of a once continuous distribution along the boundary currents of the Atlantic and Pacific oceans (Be, and Gilmer, *Oceanic Micropaleontology*, Vol. 1, Ch. 6, pg. 756). Therefore, are these still the same species? Genetic studies of these species, taken from samples from the California current and Georges Bank, will help to identify viable genes that will distinguish the different possible species. Research for this project is also being conducted at the University of New Hampshire. On this cruise samples were collected at every station for genetic studies with net # 5 on the 1-m² MOCNESS. At selected stations, 90 ml sub-samples from the bottom and surface 1-m² MOCNESS (150 um mesh nets) samples, were taken. All samples were preserved in 95 % ethanol which was changed 24 hours after collection.

High Frequency Acoustics

(Peter Wiebe and Erhan Mutlu)

The primary focus of the bioacoustical effort on this cruise was to make high resolution volume backscattering measurements of plankton and nekton throughout the Georges Bank region. The acoustical data are intended to provide acoustical estimates of the spatial distribution of biomass of acoustical targets which span the size range of the target species (cod, haddock, *Calanus*, and *Pseudocalanus*) and their predators. Work on this cruise was designed to provide intensive continuous acoustic sampling along all the shipboard survey track lines in order to cover the entire Georges Bank region. The spatial acoustical map is also intended to provide an essential link between the physical oceanographic conditions on the Bank and the biological distributions of the species as determined from the net collections at the stations distributed throughout the Georges Bank region. Continuous acoustic data between stations can be used to identify continuity or discontinuity in water column structure which can in turn be used to qualify the interpretation of biological and physical data based on the point source sampling.

The acoustic and environmental sensor packages were mounted in an ENDECO towed 5-foot V-fin fish nicknamed the "Greene Bomber". The tow-body has been described in Wiebe and Greene (1994 - Figure 1). For this cruise, the interior of the tow-body carried a BioSonics, Inc. 120 kHz digital transducer and a transmitter pressure case. The transducer was operated in a down-looking mode. In addition, an environmental sensing system was mounted inside the V-fin with temperature, conductivity, and fluorescence sensors attached to a stainless steel framework outside of the fiberglass housing. A downwelling light sensor was attached to the tail. The tow-body was deployed from the starboard quarter of ALBATROSS and collected data both during and between stations. The general towing speed was 7.5 to 8 knots. The echosounder collected data at about one ping per second. Conditions for conducting an echo sounder survey of the Bank were ideal during this cruise because there was very little wind and the seas remained flat for essentially the entire cruise which was also the case during the June 1996 cruise. As a result acoustical data were successfully

obtained along the entire cruise track i.e. Standard Stations 1 to 40 - distance traveled was ~800 nm (Figure 2; Table 1).

The acoustical mapping reinforced earlier observations and provided additional insights into the structure of the water column and the distribution of the animals. Overall the values were similar to those collected during June 1996, but lower than those collected in July 1995.

The large scale picture from the acoustical records showed relatively low volume backscattering off the Bank, higher backscattering in the vicinity of the shelf water/Slope Water front, somewhat lower backscattering on the southern flank of the Bank, and then increasing backscatter with shoaling depths. Highest values occurred throughout the water column on the top of the Bank. The sections running from Standard Stations 9 to 19 was typical of most of the southern flank to Bank crest (Figure 3). This large scale pattern was associated with changes in vertical structure. In the deeper portions of the survey area (stratified waters), backscatter was typically stratified with highest values towards the surface, though considerable patchiness was observed both horizontally and vertically. As bottom depth shoaled and approached about 50-60 m, the vertical structure became more homogenous. This trend was substantiated further inward. At bottom depths of 30-50 m, the volume backscattering often, but not always appeared to be completely homogeneously distributed vertically. Often in the past, these have been areas where there was substantial amounts of particulate matter and sand in the water column as well as plankton some of which occurred in very small-scale surface patches. At these depths, vertical striations (i.e. bands of horizontal patchiness) were recurrently observed, a phenomenon we have postulated that is associated with vertical circulation cells caused by tidal flow over a rough bottom. Sand particles were present in many of the MOCNESS and pump plankton samples from the shallow regions of the Bank on this cruise as well, including those taken at the surface. Preliminary analysis of the effects of those particles on the backscattering, based on work conducted on the June/July cruises of the past two years, strongly indicated that signals from the sand could have overridden those of biological origin. This may have been especially true of water at Standard Stations 11, 12, and 32 where sand was observed in all of the 1-m² MOCNESS samples.

Internal waves were particularly evident in the stratified waters along the perimeter of the Bank. They were often centered between 15 and 30 meters (in the pycnocline) and typically had amplitudes of 10 to 15 meters. However, some impressive wave packets were observed which deserve description. The first encounter of a large internal wave which was quite spectacular occurred at 40 36.64 N; -67 35.95 W between Standard Stations #6 and #7 (Figure 4). This wave packet had a very interesting layering structure with three layers especially prominent. Of particular interest was the intense scattering on order 10-15 dB above background that occurred in the core layers which characterized the wave. It seems unlikely that this scattering was due to the presence of large numbers of animals since such large concentrations (as indicated by heavy scattering) were not evident on either side of the wave packet. The scattering could be due to temperature micro-structure or turbulence caused by current shear in the portion of the wave packet or both. There was very little scattering below about 40 m to the bottom at 90 m. In this case, the surface the temperature, salinity, and fluorescence data varied with the structure of the internal wave with warm, relatively fresh, and lower fluorescence values where the wave troughs occurred and colder, fresher, and higher fluorescence values close to the leading edge of the wave crests.

A wild looking internal wave occurred while steaming between Stations #17 and #18 (Figure 5). It looked a lot like the internal wave we saw between Standard Station #21 and #22 on a previous cruise that is illustrated in Wiebe *et al.*, in press). But in this case, there was a bottom feature associated with the wave that made the entire image spectacular. It is hard to imagine what the physical dynamics are that could create such an image or what role the biology in the water column might be contributing to the acoustic signal. Here the temperature, salinity, and fluorescence structure had a trend of increasing fluorescence and salinity and decreasing temperature moving from the rear to the front of the wave packet and on to the Bank. There was not, however, any particular variation in these properties that could be overtly correlated with the internal wave crest and trough structure itself. Again, it is not clear how much of the volume backscattering is due to animals in the water column or to some other feature of the wave packet.

Another spectacular internal wave packet suddenly appeared. This one started out as a feature very close to the surface and then seemed to move deeper as we steamed towards Station #22 (Figure 6). It was as if the mixed layer were very shallow at the first point of contact with the wave and then went deeper as we steamed along with the wave being focused along the descending pycnocline. It ended as a broadly-diffuse layer extending to 40 m with relatively high backscattering. Below this depth the scattering was very low to the bottom. The entire feature was about 1900 meters long.

Many of the internal waves observed on the Bank are thought to be generated as Lee waves which develop as the tidal flow is moving off the Bank. Between Standard Stations # 24 and #39, we observed what looked to be a Lee wave at its point of origin just off the Northeast Peak in the Northeast Channel (Figure 7). Several bands of heavy volume backscattering characterized the structure of the wave and it is evident that its presence was felt from the surface to at least 100 m. The abrupt increase in surface temperature and salinity at the start of the wave formation and some smaller variations over the top of the wave appeared to reflect some of the internal wave structure, but the fluorescence did not.

The steam from Standard Station # 39 to #25 across the Northeast Channel yielded a variety of acoustical structures (Figure 8). Multiple layers were evident often influenced by internal waves. At the surface while leaving Station # 39, there was quite a strong volume backscattering surface layer (upper 10-20 meters). In the vicinity, a Right Whale was sighted around the ship and a few minutes earlier another report of a whale sighting was made. Along the way, we crossed over several very strong surface patches of scatterers and another whale was sighted in one of them. The patches were estimated to be between 300 and 500 meters across. At Station # 39, there were lots of *Calanus* both in the surface waters and at depth. There were also good numbers of Euphausiids in the lower depths (200-100 m) and lots of amphipods and moderate numbers of *Clione limacina* in the intermediate depths. The whales may have been feeding on *Calanus* in patches like the ones we observed steaming away from Station # 39.

We saw few strong acoustical targets that could have been fish schools in all of the surveying of the Bank. In the area that was crossed on steaming from Standard Station # 26 to #27, we did observe fish school targets on the echogram (Figure 9). They were principally at depths of 40 to 70 m.

Finally, we made acoustical observations that sometimes left us wondering, What is it? One such observation was made while steaming between Standard Station # 28 on the Northeast Peak and # 29 in Georges Basin (Figure 10). As we left the Bank and the topography dropped off rapidly, heavy volume backscattering was observed at the 100 m depth extending from right on the bottom up 30 to 40 meters into the water column. It is not clear what was the cause of the volume backscattering. Further offshore, there was a large patch of intense scattering that was linked to an internal wave, but it was very complicated and not entirely-wave like. This section occurred during the period of sunrise and a part of the acoustical structure could have been due to the migration of animals from the surface layer to deeper daytime depths.

No substantial diel changes in vertical distribution could be seen in the acoustical records on the Bank, while diel vertical migration was evident in the waters of Georges, Franklin, and Wilkinson Basin.

Secondary Cell Circulation Experiment.

On the last full day of the cruise (June 27, 1997), we conducted an experiment to test the idea that the vertical lineations in acoustical structure that are so evident in many of the well-mixed areas of Georges Bank were associated with vertical circulation cells created by strong tidal flow over an irregular bottom. The experiment was nearly identical to the one conducted in June 1996 and consisted of (1) a CTD-Fluorescence cast, (2) water sampling with the Pacer Pumping system and a MOCNESS to collect organisms and suspended sediments, (3) high frequency acoustical measurements made with the Greene Bomber (120 kHz) along a grid of transect lines laid out relative to a drogue which traced the horizontal motion of the water, (4) measurements of horizontal and vertical currents made with the ship's 300 kHz ADCP, and (5) a horizontal CTD-Fluorescence transect. The ADCP settings were changed from those typically used while mapping the entire Bank to values that increased our ability to measure fine-scale horizontal and vertical velocity field while doing the experiment (Table 2).

After completing the work at Standard Station 37, the ALBATROSS steamed back toward Standard Station 11 where earlier in the cruise there had been strong visual as well as acoustical evidence that such cells were in existence. Once in shallow water about 15 nm from Standard Station 11, the echograms showed the now familiar vertical lineation signature of a well-mixed water column. We steamed directly to the site where the study was conducted last year and commenced the experiment with the CTD cast to confirm that the water column was well-mixed (i.e., isothermal and isohaline) which it was.

A Pacer pump profile was done to quantify the amount of sand in the water column greater than 35 μm . The pump sampled for 3 to 5 minutes (approx. 1 to 2 m^3) at five depths: 45 m (5 m above the bottom), 30 m, 20 m, 10 m, and 5 m. Sand was present in all five of the pump samples. This was followed by a 1- m^2 MOCNESS tow taken in the ~45 m water column sampling 5 meters above the bottom to 25 m, 25 to 15 m, 15 to 5 m, and 5 to 0 m using 150 μm mesh nets. These samples were intended to provide material for developing the zooplankton and sand particle size and abundance data needed to interpret the acoustical data.

A high flyer drifter, with a piece of MOCNESS netting tied off at 15 m to serve as a sub-surface drogue, was creatively assembled by Willy Amaro, Toni Vieiro, and Ernest Foster (Figure 11). This drifter was launched after the MOCNESS was finished and was used as the point of navigation for a six legged grid along which the acoustical survey was conducted. The square grid, one nautical mile on a side, was laid out on the ship's radar scope and the ship was steamed (under the excellent guidance of Captain Jack Moakley) so that the drifter's radar reflector appeared as a target that moved along the grid lines. Beginning at 1030, three legs of the grid were run east/west and three were run north/south. The parallel legs were separated by a half mile. At the beginning, middle, and end of a grid line, times were marked and the ship's GPS position and the range and bearing of the drifter were obtained so that the path of the drifter could be determined (Table 3). Along the trackline, Greene Bomber observations were made of volume backscattering throughout the water column at 120 kHz and surface temperature, conductivity, and fluorescence measurements were made. Velocity measurements were made with the ADCP. Finally, Maureen Taylor deployed the CTD-Fluorometer at a depth of 35 meters and made a one nautical mile horizontal transect as we started steaming for Standard Station # 38 to investigate the possibility that patchiness of phytoplankton fluorescence at that depth might also be associated with secondary cell circulation.

Sea conditions were ideal for this experiment because there was very little wind and the sea was almost flat; only a slight swell was running. The experiment was completed at 12:56 with excellent preliminary results (Figure 12a, b)

References

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- Wiebe, P.H., T.K. Stanton, M.K. Benfield, D. Mountain, and C.H. Greene. In press. High frequency acoustic volume backscattering in the Georges Bank coastal region and its interpretation using scattering models. In. "Shallow water acoustics, geophysics, and oceanography". *IEEE Journal of Oceanic Engineering*.

Figure legends

- Figure 1.,,,,,,,,, Greene Bomber being launched from starboard quarter of the Albatross on AL9707. (Digital photo by Denise Gruccio).
- Figure 2.,,,,,,,,, Acoustic measurements were made along the entire trackline of the cruise starting at Standard Station 1 and ending at Station 38. In addition, acoustics data were collected at an experimental site located west of Station 11 at the end of the cruise.
- Figure 3.,,,,,,,,, Acoustic sections running across the southern flank of Georges Bank from the Slope Water to the crest of the Bank.
- Figure 4.,,,,,,,,, An internal wave packet between Stations 6 & 7.
- Figure 5.,,,,,,,,, An internal wave packet between Stations 17 & 18.
- Figure 6.,,,,,,,,, An internal wave between Stations 21 & 22.
- Figure 7.,,,,,,,,, A possible Lee wave between Standard Stations 24 and 39.
- Figure 8.,,,,,,,,, Acoustical Section across the Northeast Channel between Standard Stations 39 and 25.
- Figure 9.,,,,,,,,, Possible fish schools (herring??) between Standard Stations 26 and 27.
- Figure 10.,,,,,,,,, Acoustical Section from Northeast Peak Standard Station 28 and Georges Basin Standard Station # 29.
- Figure 11.,,,,,,,,, The Secondary Cell Experiment drogue and its makers.
- Figure 12. ,,,,,, A) Three panels showing the ship track over the ground while following the drogue, the path of the drogue during the experiment, and the ship track relative to the drogue. B) A 3-D view of the acoustic data collected during the Secondary cell Circulation Experiment.

Table 1. Acoustic Data Summary and concomitant observations. Note that acoustic data files are written in one hour blocks on a continuous basis while the software toggle switch "record data" is on. Thus, there should be as many hourly data files as there are hours between the "time in" and the "time out".

Run#	LAT, N LON W	Local	GMT	ESS Data files	Remarks
		Date Time in Time out	Date Time in Time out		
1	40 56.3 69 00.4 40 38.4 69 01.4	June 19 0329 June 19 0734	June 19 1729 June 19 1134	a9707_01.pro a9707_01.raw	Tow started at the end of Station 1 (Yearday 170) and ended at the end of Station 2 (Yearday 170). 1-m ² MOCNESS #2 Distance traveled on run#1: 38.9 km (21 nm).
2	40 38.4 69 01.4 40 27.1 67 17.9	June 19 0736 June 20 0934	June 19 1136 June 20 1334	a9707_02.pro a9707_02.raw a9707_03.pro a9707_03.raw a9707_04.pro a9707_04.raw	Tow started at the end of Station #2 (Yearday 170) and ended at the beginning of station #7 (Yearday 171). 1-m ² MOCNESS #3,4,5,6 Distance traveled on run#2: 204.17 km (110.24 nm).
3	40 28.2 67 16.9 40 58.3 67 19.5	June 20 1047 June 20 2113	June 20 1447 June 21 0113	a9707_05.pro a9707_05.raw	Tow started at the beginning of the MOCNESS tows during Station 7 (Yearday 171) and ended at the beginning of station #9 (Yearday 171). 1-m ² MOCNESS #7 and #8 Distance traveled on run#3: 76.6 km (41.4 nm).
4	40 58.4 67 20.2 41 15.7 67 10.2	June 20 2133 June 21 1452	June 21 0133 June 21 1852	a9707_06.pro a9707_06.raw a9707_07.pro a9707_07.raw a9707_08.pro a9707_08.raw	Tow started during the MOCNESS tow # 9 (Yearday 171) in the middle of Station #9 and ended right after the Bongo in middle of station #13 (Yearday 172). 1-m ² MOCNESS #9, 10, 11, 12 and 13., Distance traveled on run #4 136.3 km (73.6 nm)
5	41 15.3 67 09.4 41 14.7 67 09.3	June 21 1525 June 21 1723	June 21 1925 June 21 2123	a9707_09.pro a9707_09.raw	Tow started just after the pump work in middle of Station #13 (Yearday 172) and ended at the end of this same station to do another check out following a problem with the towing. No along track distance traveled.
6	40 14.6 67 08.9 < 41 11.9 66 27.1	June 21 1727 June 22 1136	June 21 2127 June 22 1536	a9707_09.pro a9707_09.raw a9707_10.pro a9707_10.raw	Tow started at the end of Station #13 (Yearday 172) after a check out following a problem with the towing and ended at the beginning of station #17. No data from #13 to # 14 due to record failure. MOCNESS tow # 14, 15, 16. Distance (#14-#17 traveled on run #6 83.65 km (45.2 nm)
7	41 11.9 66 27.5 41 43.4 66 31.8	June 22 1159 June 23 0715	June 22 1559 June 23 1115	a9707_11.pro a9707_11.raw a9707_12.pro a9707_12.raw a9707_13.pro a9707_13.raw	Tow started in the middle of Station #17 (Yearday 173) during the pump work after a re-rigging of the line holding the electrical cable and ended at the end of station #20 because of a cable problem. MOCNESS tow # 17,18,19,20. Distance traveled on run #7 103.1 km (55.7 nm)
8	41 40.2 66 30.0 41 45.9 66 09.9	June 23 0742 June 23 1802	June 23 1142 June 23 2202	a9707_14.pro a9707_14.raw	Tow started after fixing the cable and connector after leaving Station #20 (Yearday 174) and ended with another cable snafu just before arriving at Station #23. MOCNESS tow #21,22. Distance traveled on run #8 85.4 km (46.1 nm)

9	41 46.4 66 10.8 42 19.4 65 53.0	June 23 1920 June 24 1216	June 23 2320 June 24 1616	a9707_15.pro a9707_15.raw a9707_16.pro a9707_16.raw	Tow started after the CTD cast at Station #23 (Yearday 174) and ended at the end of station # 25. MOCNESS tow # 23,24, 25 (st39), 26. Distance traveled on run #9 69.0 km (37.2 nm)
10	42 18.2 65 52.7 42 04.7 66 26.0	June 24 1303 June 24 1720	June 24 1703 June 24 2120	a9707_17.pro a9707_17.raw	Tow started the end of Station #25 (Yearday 175) after a routine checkout of the fish and ended after the first Bongo at station #26. Distance traveled on run #10 54.2 km (29.3 nm)
11	42 04.7 66 26.0 42 03.7 66 23.5	June 24 1727 June 24 1942	June 24 2127 June 24 2342	a9707_18.pro a9707_18.raw	Tow started after the Bongo at Station #26 (Yearday 175) and ended at the same Station to put lead weight on fish. MOCNESS tow # 27. No along track distance.
12	42 03.5 66 23.5 42 10.0 67 39.6	June 24 1945 June 25 1955	June 24 2345 June 25 2355	a9707_19.pro a9707_19.raw a9707_20.pro a9707_20.raw	Tow started at the end of Station #26 (Yearday 175) and ended at the beginning of station # 40. MOCNESS tow # 28,29, 30. Distance traveled on run #12 169.2 km (91.4 nm)
13	42 10.1 67 40.2 41 41.4 67 39.5	June 25 2007 June 26 0602	June 26 0007 June 26 1002	a9707_21.pro a9707_21.raw a9707_22.pro a9707_22.raw a9707_23.pro a9707_23.raw	Tow started during the Bongo tow at Station #40 (Yearday 176) and ended at the beginning of station #32 to fix salinity cable. MOCNESS tow # 31, 32 (sta 40), 33. Distance traveled on run #13 52.8 km (28.5 nm)
14	41 40.3 67 37.8 41.27.5 68 57.5	June 26 0658 June 27 2204	June 26 1058 June 28 0204	a9707_24.pro a9707_24.raw a9707_25.pro a9707_25.raw a9707_26.pro a9707_26.raw	Tow started just after the start of the MOCNESS-10 trawl at Station #32 (Yearday 177) and ended after the end of MOCNESS-10 trawl at station # 38. MOCNESS tow #35,36,37,38,39,40, 41. Distance traveled on run #14 228.2 km (123.2 nm)

Table 2. The configuration settings of the ADCP used during the Secondary Cell Circulation Experiment.

BEGIN RDI CONFIGURATION FILE

COMMUNICATIONS

```
{
ADCP_..... ( ON_ COM1 9600 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
ENSOUT_..... ( OFF COM4 9600 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
NAV_..... ( ON_ COM3 4800 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
REFOUT_..... ( ON COM2 9600 N 8 2 ) [ Port Baud Parity Databits Stopbits ]
EXTERNAL_..... ( OFF COM4 9600 N 8 1 ) [ Port Baud Parity Databits Stopbits ]
}
```

ENSEMBLE OUT

```
{
ENS CHOICE_ ( N N N N N N N ) [ Vel Corr Int %Gd Status Leader BTrack ]
ENS OPTIONS ( NONE 1_ 8_ 1_ 8 ) [ Ref First Last Start End ]
}
```

ADCP HARDWARE

```
{
Firmware_..... ( 4.15 )
Angle_..... ( 30 )
Frequency_..... ( 300 )
System_..... ( BEAM )
Mode_..... ( 4 )
Orientation_ ( DOWN )
Pattern_..... ( CONCAVE )
}
```

}

DIRECT COMMANDS

```
{
WS100
WF200
BX800
WN080
WD111100000
WP00010
BP005
WM4
TP000025
BM0
EZ1121111
}
```

RECORDING

```
{
Deployment ( G96A )
Drive 1,,, (,, C )
Drive 2,,, (,, C )
ADCP,,,,, ( YES )
Average,,, ( YES )
Navigation ( NO )
}
```

CALIBRATION

```
{
ADCP depth,,,,,,,,, ( 5.00 m,,,, )
Heading / Magnetic offset (,, 0.00,,,,, 0.00 deg )
Transducer misalignment,,, (,, -0.50 deg )
Intensity scale,,,,,,,, (,, 0.43 dB/cts )
Absorption,,,,,,,,, (,, 0.062 dB/m,, )
Salinity,,,,,,,,, (,, 35.0 ppt,, )
Speed of sound correction (,, NO,, 1500.0 )
Pitch & roll compensation (,,, YES,,,, )
Top discharge estimate,,, (,, CONSTANT )
Bottom discharge estimate (,, CONSTANT )
Power curve exponent,,,,, (,,,,, 0.1667,, )
}
```

PROCESSING

```
{
Average every ( 3.00 s )
Depth sounder ( NO )
Timeout ( OFF )
Refout_info (,, 1,, 8 1.00,, 1.000 ) [bins: 1st last, KtsChngLimit, NewWeight]
External_formats ( N N Y N ) [ HDT HDG RDID RDIE ]
External_decode ( Y N N N ) [ heading pitch roll temp ]
}
```

GRAPHICS

```
{
Units,,,,, ( SI )
Velocity Reference ( NAVIGATION )
East_Velocity,,,,, ( -150.0 150.0 cm/s )
North_Velocity,,,,, ( -150.0 150.0 cm/s )
Vert_Velocity,,,,, ( -50.0 50.0 cm/s )
Error_Velocity,,, ( -50.0 50.0 cm/s )
Depth,,,,,,,,, (,,,,, 1,,,, 80,, bin )
Intensity,,,,,,,,, (,,,,, 0,, 200,,,, dB)
Discharge,,,,,,,,, ( -1000 1000 m3/s )
East_Track,,,,,,,,, ( -156610 300000,,,, m )
North_Track,,,,,,,,, ( -364401 364401,,,, m )
Ship track,,,,, ( 1 bin 100.0 cm/s )
Proj_Velocity,,,,, ( -100.0 100.0 cm/s )
Proj_Angle,,,,, ( 0.0 deg from N )
Bad_Below_Bottom (,, NO )
Line1,,,,,,,,, (,,,,,,,,, )
Line2,,,,,,,,, (,,,,,,,,, )
}
```

HISTORY

```
{
```

```
SOFTWARE,,,,,( BB-TRANSECT )
Version,,,,, ( 2.72 )
```


}

END RDI CONFIGURATION FILE

Table 3. Location of ship during the Secondary Cell Circulation Experiment grid survey with range and bearings to the drogue (AL9707).

Mark	Leg	Approx. heading	Time	Lat (N)	Lon (W)	Range (nm)	Bearing
1	1	W	1031	41 16.337	68 15.731	1.01	180
2		W	1039	41 16.245	68 16.456	1.10	153
3		W	1046	41 16.199	68 17.169	1.38	134
4	2	E	1057	41 15.570	68 17.295	1.07	112
5		E	1105	41 15.567	68 16.716	0.68	132
6		E	1112	41 15.524	68 16.122	0.45	179
7	3	W	1122	41 15.051	68 16.234	0.01	000
8		W	1130	41 15.024	68 17.028	0.50	084
9		W	1137	41 15.067	68 17.808	1.00	087
10	4	N	1146	41 15.120	68 17.945	0.99	087
11		N	1154	41 15.681	68 18.105	1.12	113
12		N	1202	41 16.285	68 18.222	1.41	134
13	5	S	1212	41 16.410	68 17.685	1.11	153
14		S	1221	41 15.983	68 17.902	0.67	132
15		S	1229	41 15.598	68 18.098	0.51	086
16	6	N	1237	41 15.763	68 17.625	0.01	090
17		N	1245	41 16.330	68 17.698	0.45	181
18		N	1252	41 16.995	68 17.855	0.98	179

Drifter Deployments.

As part of the physical oceanographic studies of the current structure and circulation on Georges Bank being conducted by R. Beardsley and R. Limeburner, GLOBEC drifter buoys are deployed at strategic locations periodically throughout the year to track the Lagrangian flow from the point of deployment. This drifter is constructed with a holey sock drogue (a Dacron cylinder 90 cm diameter by 3 m tall with 5 circular hoop stays) at the bottom connected by either a 10 m or a 40 m cable to a small float (18 cm diameter) which in turn is connected by about 2.6 m of cable to a larger spherical surface float (about 32 cm diameter). The surface float contains a sea surface temperature sensor, a GPS receiver, and an ARGOS satellite transmitter. Temperature, time, and position data are transmitted periodically to shore through the ARGOS telemetry system. On this cruise, three drifters were deployed: one at standard station #38 (consecutive station #41) that was drogued at 10 m; and one at standard station #34 (consecutive station #36) that was drogued at 10 m, and a second at 40 meters.

Shipboard ADCP (Acoustic Doppler Current Profiler) Measurements.

The flow field over Georges Bank is driven by a complex set of forces. A primary factor is the strong semidiurnal tides which dominate the high frequency variability (<1cpd) of the currents. Tidal rectification gives rise to a persistent subinertial clockwise circulation over the bank. This circulation process can be substantially modified by the frequent storms common to the area, changes in the stratification of the bank, and interactions with currents generated by offshore circulation features (i.e. warm-core rings).

The Acoustic Doppler Current Profiler is one of the instruments being used to study the circulation process on the bank by J. Candela and C. Flagg. Water current measurements were obtained using a 150 kHz RDI ADCP continuously during the entire cruise. The transducers were mounted on the hull of the ship (5 m below the surface with a heading offset (OH) of -1.5°). The instrument was programmed to measure the current profile under the ship with a vertical resolution of 2 m, from 10 m depth to about 10 m from the bottom or up to a depth of about 120 m, which ever was shallower at a given location. The current profiles were generated by 60 s data averages. Transformation to geographical North and East current components was performed using real time gyro information fed into the ADCP from the ship's navigation instrumentation. Also fed to the instrument was real time GPS positioning which was stored directly in the minute average profile data files. The ADCP measures currents with respect to the ship. To obtain the water current with respect to the ocean bottom, the ship's motion needs to be removed from the current observations. The ship's motion will be removed using the bottom track (BT) velocity measured by the ADCP. Depending upon sea conditions, the ADCP can perform this operation in depths shallower than 200 to 230 m. When the BT is lost, accurate navigation will be used to remove the ship's velocity from the current.

The ADCP data collected on this cruise will be post-processed at Woods Hole Oceanographic Institution by Candela and Flagg.

Personnel List

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R/V Albatross IV, Personnel

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 Denise Gruccio Acting Executive Officer
 Philip Gruccio Acting Operations Officer
 John Hurder Acting Chief Mechanical Engineer
 Chuck Hersey Acting First Assistant Engineer
 Grady Abney Third Asstant Engineer
 Willy Amaro Lead Fisherman
 Tony Vieira Skilled Fisherman
 Tony Alvernaz Chief Bosun
 Richard Whitehead .. Chief Steward
 Jerome Nelson Chief Cook
 Doug Roberts Fisherman
 Ernest Foster General Vessel Assistant
 Bobby Yates , Electronics Technician
 John Fallin Electronics Technician

Appendix 1. List of Station and Underway Activities

Appendix 2. CTD Plots and Compressed Listings of Data